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14. ABSTRACT
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FOIL IMPLOSION STUDIES ON PEGASUS*

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Abstract

PEGASUS is a 1.5 MJ capacitor bank facility used in the Los Alamos Trailmaster foil implosion program. The experiments on this facility are to serve as a diagnostic testbed and foil physics benchmark for foil implosions with explosive generators as drivers. During the first year of operation, foil implosions have been driven by discharging the bank directly into a very thin Aluminum 2500 Å thick free-standing foil without any pulse sharpening techniques; so-called "direct drive." These direct drive experiments have served as initial tests to optimize bank performance and foil implosion experimental techniques. The results to date are presented below.

PEGASUS Facility

The PEGASUS pulsed power facility is a 1.5 MJ, 216 μf, 120 kV capacitor bank. With our present load chamber, which is designed for use on explosive generators as well as with the capacitor bank, the rise time of the current is ~ 4 μs. Total inductance is 27 nh and the bank inductance is ~ 4 nh. The capacitors are Maxwell 60 kV, 6 μf capacitors arranged into four modules on the periphery of a 20-ft diameter radial transmission line. The modules, similar to the Maxwell Shiva modules, are charged to a maximum of ± 60 kV forming a two stage Marx. For the data presented here, the capacitors are protected from excessive ringing by a 100 mΩ SS foil resistor connected between the plates of the transmission line to the addition inherent resistance of the PEGASUS bank of 0.5 mΩ. The modules were switched via detonator switches. For reasons given below, Maxwell rail-gap switches have now been installed as start switches.

The maximum current of the capacitor bank into the load chamber in present use is ~ 10 MA. To date, a peak current of 7 MA has been delivered into a dummy load at 88 kV charge voltage. With direct drive experiments, the foil implodes in ~ 2 μs or less at about half the quarter-cycle time of the bank. Thus, generating more current means more energy is dissipated in the load chamber as diminishing returns are realized in foil energy as voltage and current are raised. Our next set of experiments will use a Plasma Flow Switch as a pulse sharpening device so that it will be possible to drive the foil implosion at the peak current of the capacitor bank and deliver maximum energy into the foil.

Detonator switches were chosen initially for reasons of cost, because their current and coulomb capacities are very high, and because of their high reliability. (Detonator switched operation has not resulted in any pre-fires during the past year.) However, jitter has proven with the detonator switches to be a problem. We have made continuing improvements in the switches but there remains a "foot" where $\dot{I}$ initially is less than expected by ~ 30-50% for a period of 300-500 ns. Since a precisely known current vs. time profile is required to investigate 2-D effects of foil instabilities during the implosion, we are replacing the detonator switches with rail gaps. Because of the coulomb limit of the rail-gap switches, detonator-switched crowbars will be used for capacitor bank operation at voltages significantly above 80 kV.

The load chamber (powerflow channel) is shown below in Figure 1. The coaxial section, ~ 40 cm diameter, mounts onto either our capacitor bank or an explosive generator. The negative electrode (Aluminum) is soft-anodized and the channel is routinely hi-potted to 160 kV DC before use on a foil implosion.

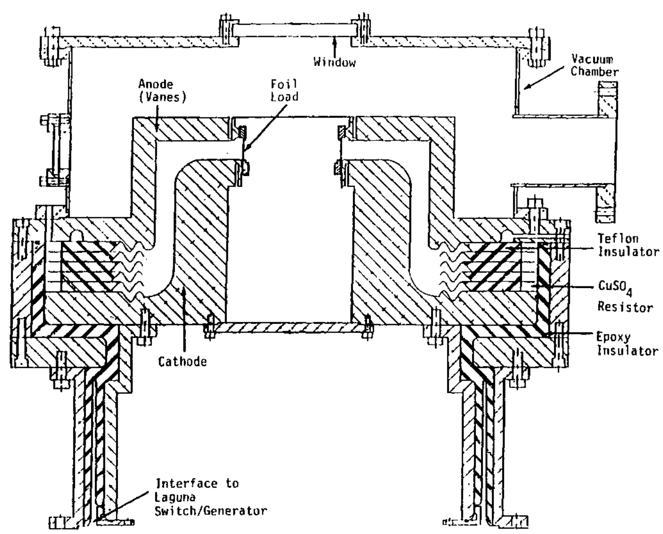

Figure 1. Powerflow Channel.

Vacuum pressures are typically mid-10^{-5} torr when we fire. We have not observed shorting of the channel during the initial 1/4-cycle of the current rise. The foil mounting rings are held in place by spring loaded fingers, which are under load when the foil manufacturing mandrel is removed. (The mandrel has similar spring loaded fingers to grip the foil rings.) This technique allows the free standing, 2500 Å thick, 2-cm high, 10-cm diameter Aluminum foil to be installed with a minimum of wrinkles.

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**R&D Associates, Alexandria, Virginia, 22314.

Experimental Results

Diagnostics fielded on the experiments include a Rogowski, a capacitive V probe, several channels of Faraday-rotation current measurements, a four-channel XRD array, an x-ray pinhole camera, a single channel bolometer, VUV spectrometer, and optical cameras. Current (I) vs. Time data (shown in Figure 2 below) shows the effect of the foil implosion as an ~ 50% notch at ~ 2 μsec on the rise of the current.

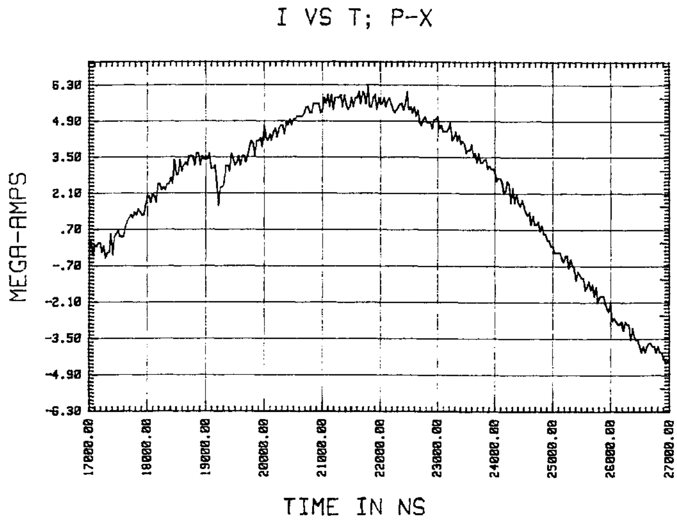

Figure 2. Effect of the foil implosion at the rise of the current.

Calculated, slug-model implosions occur about 100-300 ns earlier than experimentally observed; however, the detonator switches are believed to have a resistive phase which retards the initial rise of the current. The current values at implosion time and magnitude of the current dip are in agreement between the experimental and calculated values. The slug-model implosion on the whole appears to characterize the coarse features of the foil implosion.

The bolometer measured 39 kJ of radiated energy for shot no. 10 from 50 eV to 2 keV. An energy estimate made from the above current dip yields ~ 100 kJ into foil kinetic energy. The capacitative voltage probe located on the powerflow channel (halfway along the feed system inductance) showed a 400 kV spike at foil implosion time. XRD data shows an x-ray burst at implosion time with width of 200 ns. The burst has two peaks. These results are typical. The twin peaks (at the beginning to end of the pulse) possibly suggest a precursor of foil mass arriving on axis before the main implosion. A typical width is 200 ns, though we have had a width of 150 ns on one shot. Effective blackbody temperature of ~ 20 eV is inferred from the XRD data assuming a 1 cm diameter source. Efforts are presently underway to measure the diameter of this source.

Summary

Direct-drive foil implosion shots fired to date on PEGASUS have provided results in good agreement with slug model calculations. Instability issues and 2-D effects will be addressed in a series of shots using the newly installed Maxwell rail-gap start switches. This upcoming shot series will conclude direct drive experiments by providing implosion data for benchmarking codes capable of tracking Raleigh-Taylor instabilities. Pulse-sharpened plasma-flow switch experiments which follow will be designed and analyzed utilizing these codes.

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References

[1] J. H. Degnan, et al., IEEE Trans. Plasma Sci., Vol. PS-15, No. 6, pp. 760-756, 1987.